BULLETIN 656 MARCH, 1945

Hay-Crop Silage

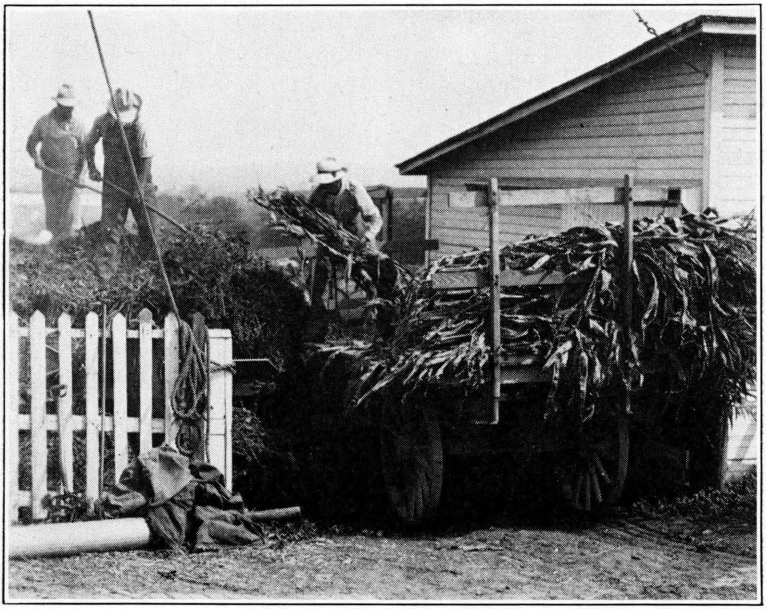
A Summary of Ten Years' Work

C. C. Hayden, A. E. Perkins, C. F. Monroe, W. E. Krauss,
R. G. Washburn, and C. E. Knoop

OHIO
AGRICULTURAL EXPERIMENT STATION
Wooster, Ohio

This page intentionally blank.

CONTENTS



Formerly a job limited to a brief period in early fall, silo filling may now be done with various crops or crop mixtures throughout the growing season.

Above: Clover and green wheat are unloaded from separate wagons into the same cutter to make a mixed silage of high quality.

Below: Corn and soybeans work well together in the silo in widely varying proportions.

New machinery will eliminate much of the hand labor now involved in silage making.

HAY-CROP SILAGE

A Summary of Ten Years' Work

C. C. HAYDEN, A. E. PERKINS, C. F. MONROE, W. E. KRAUSS,
R. G. WASHBURN, AND C. E. KNOOP

INTRODUCTION

The making of legume and other hay crops into silages is not new. No one seems to know just when it began. It was practiced in Europe with other forages many years before corn was used for silage.

It was learned early that the development of acids aided in preventing decomposition and especially prevented the development of undesirable odors. Acids, mainly lactic and acetic, are developed largely from the sugars contained in the sap of the green plants during the natural processes of making silage. Organic or mineral acids have sometimes been added to forage to supplement or replace the organic acids developed from the plant sugars.

Corn contains an abundance of sugars and is low in protein at the stage at which it is harvested for silage; therefore, acids develop quickly in corn silage. This holds less desirable fermentations in check so that good silage usually results.

It was believed by many that legumes, because of their relatively low sugar content and their higher protein content, could not be ensiled safely, since proteins are subject to undesirable fermentations. To overcome this difficulty, thirty or more materials and many combinations of these materials have been tested as preserving agents. Those found to be most practical are molasses, ground cereal grains, combinations of green crops, and mineral acids. Recent work tends to show that such additions are not as important as it was formerly believed.

In order to contribute to the basic knowledge regarding silage making and to check the suitability of various materials and methods for use under Ohio conditions, many lots of silage have been made in both small and in practical-sized silos at the Ohio Agricultural Experiment Station. From 1932 to 1942 69 lots of hay-crop silage were made by the Department of Dairy Industry. Some of these lots were treated in various ways; others were left untreated for comparison. The results are summarized in this publication. Data obtained on many more lots made in small drums and small laboratory silos are not included in this report.

LITERATURE

There are now hundreds of references to articles and reports of experiments on the subject of hay-crop silage. It is not practical to give a review of all of this literature; hence, only a few key references will be cited here.

King (9), as early as in 1897, said that clover could be made into silage and fed more cheaply as silage than as hay and that best results were obtained when the material contained from 28 to 32 per cent of dry matter.

Eckles and Palmer (4) of Missouri showed that good legume silage could be made without the addition of acid-producing agents. Woodward and Shepherd (22) have also shown that good results can be obtained by reducing the moisture content by wilting. Investigators in Europe tested various acids, combinations of acids, molasses, sugars, and other products and processes. The results of these trials were well summarized by Watson (21). There is also a review by Bender and Bosshardt (2).

The use of hay-crop silage was not seriously considered in most parts of the United States until quite recently. The greatest advance has come within the last 10 years, due mainly to the following factors: The uncertainties of hay harvesting; the introduction and promotion of the A. I. V. process, with its remarkable claims for the preservation of nutrients in the silage; the soil conservation program which called for a reduction of soil-depleting crops such as corn and an increase of grass and legume crops; the greater knowledge of the importance of minerals and vitamins in animal life; and the presence of these minerals and vitamins in hay crops and the belief that they could be more completely preserved in silage than in sun-cured hay.

ACID-TREATED SILAGES

HYDROCHLORIC AND SULFURIC ACIDS

(A. I. V. PROCESS)[1]

Virtanen (20), after a study of enzymes produced by bacteria, said that these enzymes had no detrimental action on the proteins of forage crops when the pH was below 4.0. At higher pH levels proteins were broken down. Only strong mineral acids like sulfuric and hydrochloric were effective in reducing the pH below 4.0 at once. He also stated that cows had been fed up to 130 pounds daily of A. I. V. silage without ill effects.

Peterson et al. (13) ensiled alfalfa and soybeans, using two levels of the acids on the alfalfa. They obtained a pH as low as 2.1. Contrary to the claims of Virtanen, they found a breaking down of the protein of the silage and there was no marked change in milk production when cows were changed from a normal to an A. I. V. silage ration. By approximately doubling the carotene consumption through the feeding of A. I. V. silage the vitamin A content of the milk was also doubled. Only 2 per cent of the carotene ingested appeared in the butterfat.

Smyers (18) of Belgium found that the A. I. V. process made better silage than the natural process in tower silos.

Hathaway et al. (6) found that the vitamin A content of A. I. V. silage was only slightly greater than that in silage treated with molasses and that milk from cows fed good alfalfa hay was superior to that from A. I. V. or molasses-treated silage.

Watson (21) found that acid-treated crops made good silage and that the quality was correlated rather closely with the acidity or pH.

The A. I. V. patented process was introduced into Ohio in 1933 and high claims were made for its efficiency. The cost of the royalty, the high cost of

[1]The term A. I. V. was applied to the procedure of adding hydrochloric and sulfuric acids to green forage, according to specifications of the inventor of the process, A. I. Virtanen.

and difficulty of handling the acids, and the possible ill effects on the animals made it seem advisable to study the process. Therefore, two tests were conducted in 1934 to 1936.[2]

FIRST EXPERIMENT

Two 25-ton silos were filled in August, 1934, with second-crop alfalfa-clover, about one-third of which was clover (7). Four parts of 2 N hydrochloric and 1 part of 2 N sulfuric acids were mixed (the Virtanen or A. I. V. mixture) and applied by running the mixture into the blower of the silage cutter. The acids injured the silage cutter and the mist from it ruined the drive belt. Workers could not stay long in the silo. The acid was detrimental to clothing and to metal. Thereafter, all applications in large silos were made through a bronze pump and hose directly into the silo. An attempt was made to add 70 liters of the 2 N acid solution to each ton of material. However, not enough acid was added and the pH of the silage was reduced from 5.43 in the crop to 4.31 in the silage. The dry-matter content of the crop ensiled was 31.5 per cent, and that of the silage with the acids and water added was 27.5 per cent. The carotene in the green material was 97, and in the silage 42, parts per million of dry matter.

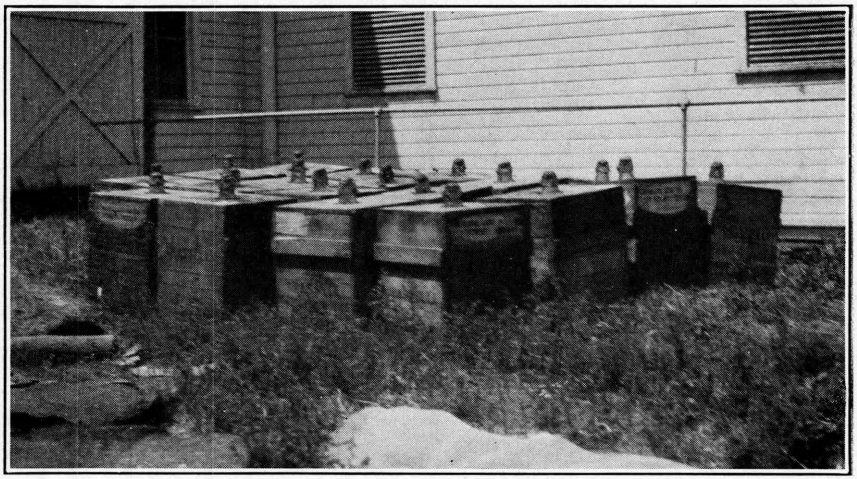


Fig. 1.—Shipping containers required to hold the hydrochloric and sulfuric acids used on 50 tons of alfalfa silage put up by the A. I. V. method. Seventeen carboys of hydrochloric and 1½ carboys of sulfuric acid were needed to bring the pH to the desired level.

One silo was opened 104 days and the other 181 days after filling. The silage was generally in excellent condition. It was fed from the two silos consecutively in comparison with good hay made from the same crop (12). Four groups (A, B, C, and D) of cows were used. Group A was fed the silage as the only roughage through a period of 115 days, and group B was fed the

[2]Brief summaries were published in the 54th and 55th Annual Reports of the Ohio Agricultural Experiment Station and in the Ohio Experiment Station Bimonthly Bulletins for November-December 1935 and January-February 1937.

hay as the only roughage through a like period. Both of these groups were fed from the same grain mixture. Group A was fed 4 ounces of finely ground limestone daily with the silage and group B 2 ounces daily with the hay. These two groups were used to study the effects of the silage on the cows and on the quality of their milk.

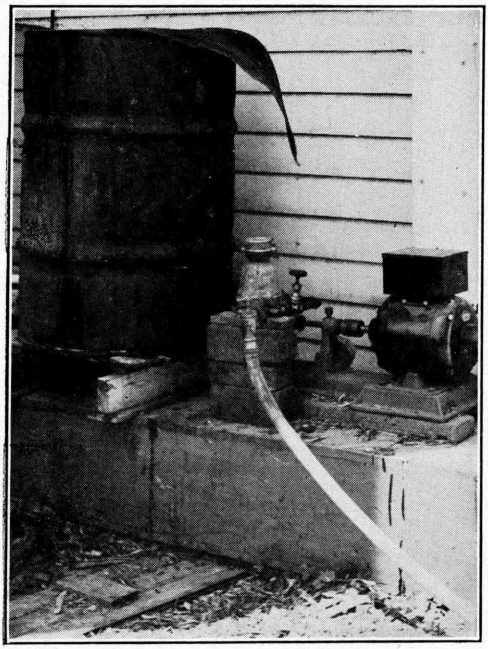


Fig. 2.—Motor-driven pump used for supplying diluted molasses or acid solutions to crops as ensiled. The liquids are conveyed through the hose to the surface of the silage.

The cows in groups A and B kept in good condition and carried calves normally. There was no visible difference. The calcium and phosphorus of the blood remained practically the same throughout the 115 days. The CO_2 capacity of the blood was changed to a slight degree and there was a drop of about 0.7 unit in the pH of the urine of the cows fed silage. This remained about the same after the first 30 days. The ammonia nitrogen in the urine increased about 15 times and the CO_2 decreased to about one-fifth the original amount. Since the blood was not materially changed, the condition of the urine can not be considered pathologic. There was no significant difference in live-weight changes. Group A consumed an average of 42 pounds of silage daily, which is not a large amount.

Groups C and D were planned to determine the value of the silage for milk production. They were fed a basal ration of corn silage and grain. In addition, one group got alfalfa hay and the other A. I. V. silage. An attempt was made to equalize the dry-matter intake from the hay and A. I. V. silage. The cows were fed through two 46-day periods, the rations being alternated.

While on the A. I. V. ration the cows produced 379.3 pounds, or 5.5 per cent, more milk (4 per cent fat basis) than while on the hay ration and they gained 131 pounds more weight.

The milk produced per unit of dry matter consumed was about 2 per cent greater from the dry matter of the silage ration. This indicates that the A. I. V. silage was slightly better than the hay from the same crop.

The carotene content of the silage was 43 per cent and that of the hay was 32 per cent of that in the green crop from which they were made. More of the carotene was carried over into the butterfat from the hay than from the silage. The vitamin A activity of the milk from the two sources gave very similar results when fed to rats. There was an indication that some growth-stimulating factor was transferred from the silage to the milk.

SECOND EXPERIMENT

A second experiment was conducted according to practically the same plan as was used in the first experiment. First-crop alfalfa-clover-timothy was used, and the silage was made as nearly as possible according to the A. I. V. plan. A sufficient amount of the acid mixture was added to lower the pH to 3.5 at once. Silage feeding began 130 days after the silo was filled. The silage was graded excellent and was well eaten by the cows. An average of 21 samples taken at various levels in the silo showed the pH to be 3.67—very close to that desired.

The average of four samples taken from the field showed 188 parts of carotene per million; seven samples taken at the silage cutter showed 130 parts per million; and 11 samples from the silage showed an apparent carotene content of 220 parts per million of air-dry matter. This apparent increase was greater toward the bottom of the silo.

The feeding plan was the same as in the preceding experiment (12). Bad weather prevented curing hay from the same crop; hence, market hay was compared with the A. I. V. silage. Grain and minerals were fed as in the first experiment.

Two groups of four cows each were fed for 161 days. Group A received silage and group B received alfalfa hay as the only roughage. Both groups received the same grain mixture. Group A ate 7.28 pounds of grain and 52.3 pounds of silage and produced 22.5 pounds of milk per cow daily. Group B ate an average of 7.36 pounds of grain and 17.64 pounds of hay and produced 19.8 pounds of milk per cow daily. While these two groups were not planned primarily to study the effect of the rations on milk production, the production seemed to hold up better on the A. I. V. silage ration.

Groups C and D were paired for milk production and received a basal ration of grain in proportion to production and 2 pounds of corn silage per 100 pounds of liveweight. The A. I. V. silage was fed to capacity to one group, and hay enough to give an equal amount of dry matter was offered to the other group. After feeding for 71 days the hay and silage were reversed and feeding continued for a second 71-day period. The first 10 days of each period were considered transitional.

The two groups while on A. I. V. silage for 61 days (transitional period not counted) produced 25,363 pounds of milk (4 per cent basis) and while on the hay ration, 23,468 pounds. The difference was 8.07 per cent in favor of the silage ration, but the cows consumed 13.8 per cent more dry matter while on this ration.

QUALITY OF THE MILK

The carotene in the milk from group A increased as the silage feeding progressed, but in the milk from group B it decreased as the hay feeding progressed.

The changes in carotene were much more marked in milk from Jerseys than from Holsteins. Similar results were obtained from lots C and D, in the reversal trial. The carotene in the butterfat followed that in the milk.

Milks from groups A and B were mineralized and fed to rats. Very slightly better responses were obtained from the silage milk. Milk from the hay-fed cows contained more vitamin D and somewhat more of the vitamin G complex. No difference was found in the vitamin C content. The surplus of vitamin C consumed in the silage was excreted in the urine.

EFFECTS ON THE COWS

The urine.—Studies were made of the urine and blood of the cows in groups A and B (continuous feeding). The pH of the urine from group A dropped suddenly about 1.5 points when the A. I. V. silage ration was started and continued at the lower level. The pH of the urine from group B, on the hay ration, remained at the original level. Similar effects were noted on the urine of groups C and D (reversal trial). Thus, the ingestion of acids added to A. I. V. silage lowered the pH of the urine. This did not occur in other cows receiving the normal organic acids of other silage.

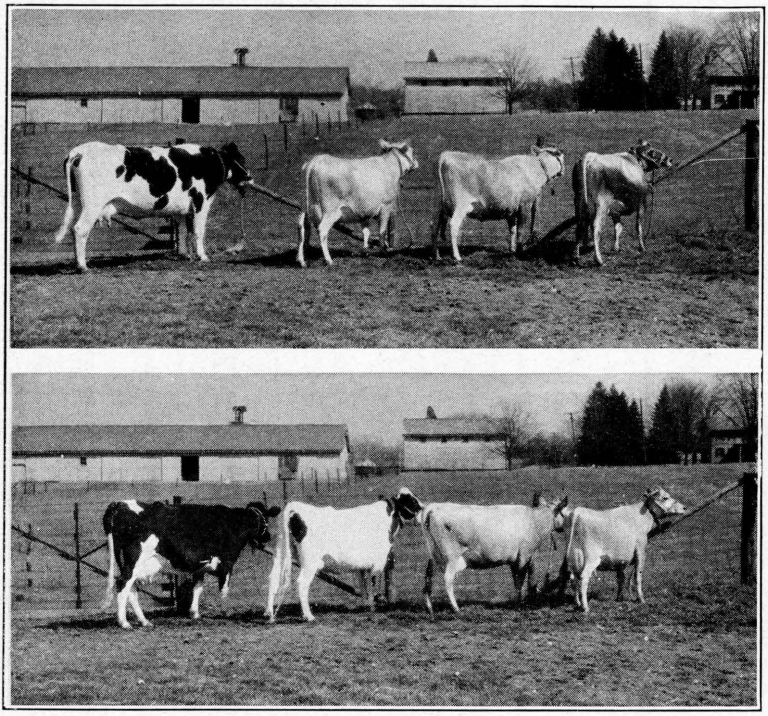


Fig. 3.—Cows on continuous feeding trials. The upper group received acid silage; the lower group received chopped alfalfa hay as the only roughage. Both groups remained in good condition and produced normally. Ground limestone was fed with the acid silage.

The bicarbonates in the urine of cows fed alfalfa hay or corn silage were many times greater than those in the urine of cows fed A. I. V. silage. The bicarbonates ordinarily excreted in the urine probably were broken down to neutralize the mineral acids from the A. I. V. silage. When lime feeding was discontinued there was a further drop in the bicarbonates on the silage ration.

The ammonia nitrogen in the urine from groups A and B (continuous feeding) was increased from a preliminary of 0.85 parts per million to 32.20 parts per million in 112 days and to 42.4 parts after the feeding of limestone was discontinued. Similar results occurred with groups C and D as the rations

were reversed. This increase did not occur with other cows when they were fed corn silage or alfalfa-wheat silage as the only roughage. It is evident that the inorganic acids (hydrochloric and surfuric) added to the A. I. V. silage required neutralization in a way not required by the regular organic acids of silage, which are utilized as food.

The blood.—Blood samples were taken at intervals and the carbon dioxide capacity determined. The average of three samples each from four cows in each of groups A and B showed 49 cc. of carbon dioxide per 100 cc. of blood from the A. I. V. group (A) and 55.4 cc. per 100 cc. of blood from the hay group (B). This slight reduction was probably not enough to constitute a pathological condition. The corresponding figures for other cows on corn silage and on alfalfa-wheat silage were 62.9 and 59.9, respectively. Determinations of the calcium and phosphorus content of the blood, made at intervals, showed there was practically no change in these constituents.

Since there was so little change in the blood, it is reasonable to assume that the acids were not seriously detrimental to the health of the cows.

Quality studies on A. I. V. silage from small silos yielded similar results (7).

PHOSPHORIC ACID[3]

Phosphoric acid was used alone and in combinations as a silage preservative in Europe by Virtanen and others (20, 21). Usually good results were reported. Virtanen did not find it equal to hydrochloric and sulfuric acids in reducing the pH.

Within the last 6 years workers at a number of American experiment stations have reported their results with phosphoric acid silage. Some of the later reports (1, 11) indicate that this kind of silage may be detrimental to cattle if fed liberally.

In the tests herein reported nine lots of legume or legume and grass silage were treated with this acid.

Lot 1.—Two 1½-ton silos were filled with comparatively clean third-cutting alfalfa in good condition. One was treated with 10 pounds of 85 per cent phosphoric acid per ton. The other was treated with 80 pounds of molasses per ton. Some water was added with both the acid and the molasses. These silos were opened 34 days after they were filled. Both silages were declared good. In a palatability test cows seemed to prefer the acid-treated silage, but the difference was small. Table 1 shows the dry matter, pH, and carotene content. (These data for all lots of phosphoric-acid silage will be found in table 1).

Lots 2, 3, 4, and 5.—Three 1½-ton-capacity wood silos were filled from a late crop of alfalfa of good quality. Two temporary, "snow-fence" silos were also filled with like material (10). The three wood silos were treated with 10, 20, and 30 pounds of phosphoric acid per ton, respectively. One of the two temporary silos was treated with 29 pounds per ton; the other one was left untreated.

These silos were opened about 40 days after they were filled. All of the silages were found to be about equally good except for heavy spoilage on the tops and sides of the temporary silos. The side spoilage was due to the poor

[3]The phosphoric acid used in these experiments was furnished by the Virginia-Carolina Chemical Company and the Victor Chemical Company.

TABLE 1.—Summary of phosphoric acid-treated legume silages

Lot	Crop used	Treatment	Air-dry matter	pH	Carotene‖	Quality
		Pounds per ton	*Pct.*		*P.P.M.*	
1.....	Alfalfa.....	10 of acid‡.....	32.25	4.60	208.0	Good
Check....	Alfalfa.....	80 of molasses.....	.....	.....	138.6	Good
2.....	Alfalfa.....	16 of acid‡	30.50	4.81	139.3	Good
3.....	Alfalfa.....	20 of acid‡	32.50	4.66	66.0	Good
4.....	Alfalfa.....	30 of acid‡	30.50	4.26	176.4	Good
5*.....	Alfalfa.....	29 of acid‡.....	27.50	5.06	129.1	Good
Check*...	Alfalfa.....	None	34.00	5.49	79.0	Good
6.	Alfalfa-clover ...	16 of acid§	28.50	4.15	249.3	Good
Check....	Alfalfa-clover ...	None	21.30	4.08	284.4	Good
7†.....	Alfalfa.....	16 of acid§	30.50	4.14	84.9	Good
8†.....	Alfalfa.....	16 of acid§	24.80	4.75	384.5	Good
9.....	Alfalfa.....	16 of acid§	20.50	4.10	278.0	Poor
Check....	Alfalfa.....	None	19.30	4.05	362.7	Poor
Average of 9 acid treated			28.61	4.50	206.1	.....
Average of 3 untreated.....			24.62	4.53	209.5	....

*Snow-fence silos.
†Upper and lower halves of same silo.
‡85% phosphoric acid.
§68% phosphoric acid.
‖Various chemical procedures for determining carotene were employed during the period covered by this bulletin. Only a few of the carotene values given are the result of chromatographic separation of carotenoid pigments in an adsorption tower. The term "carotene" as used in the text and tables includes various carotenoid pigments, as well as beta-carotene. The "carotene" values given, therefore, are in most cases considerably higher than the true beta-carotene content of the forages and cannot be used to indicate vitamin A activity.

protection afforded by the snow-fence silos. The pH was much higher in the good silage of these temporary silos than in similarly treated material in the wood silos.

Lot 6.—A 25-ton silo was filled with an alfalfa-clover mixture. The lower half was treated with 16 pounds of a 68 per cent phosphoric acid, diluted in 10 gallons of water, per ton of silage. The material placed in the upper untreated half got wet in the field, resulting in a higher moisture content. The silo was opened 78 days after it was filled. The untreated and the treated silages were graded good by all who examined them. The untreated silage with the lower dry matter had the lower pH and the higher carotene content. These silages were fed to cows on pasture (see page 11).

Lots 7 and 8.—A 25-ton silo was filled with third-crop alfalfa. The lower half was of good quality; the upper half was of overripe alfalfa with a higher dry matter and a lower carotene content. The lower half was treated with 16 pounds of 68 per cent acid, diluted with 10 gallons of water, per ton. The upper half was treated with the same, except that 20 gallons of water per ton were used with the acid in an attempt to equalize the dry matter of the upper and lower halves.

Both silages were good in quality, but the upper half was low in carotene and the lower half very high in carotene. This difference probably was due to the drier, riper material put into the upper half as compared to the lower half. These lots were compared with corn silage in a feeding trial (see page 11).

Lot 9.—Two small silos (1½-ton) were filled with first-crop alfalfa. One of these was treated with 16 pounds of phosphoric acid per ton. The acid was diluted in 10 gallons of water. The second silo was filled with like material but left untreated. These silos were opened 2 months after they were filled.

The dry matter was low in both of these silages since they had been ensiled immediately after mowing. Each had a bad odor and both were graded poor. A third silo was filled with like material but treated with corn meal. It had a slightly higher dry-matter content and was a little better, but it also had a similar bad odor. Why these three silages had a similar bad odor can not be explained unless the low dry-matter content favored an undesirable fermentation.

The phosphoric acid in the amounts used in these nine lots did not reduce the average pH as low as did the molasses in 15 lots (see tables 1 and 2). In none of the nine acid lots was it reduced below 4.0. The acid did not result in a higher average preservation of carotene than did no treatment (table 1).

FEEDING VALUE OF PHOSPHORIC-ACID SILAGE

UNTREATED AND ACID-TREATED ALFALFA SILAGE AS SUPPLEMENTS TO PASTURE

The untreated and treated silages in the silo containing lot 6 were successively fed to seven dairy cows as pasture supplements. The cows ate nearly 4 pounds more daily of the acid-treated silage. Since this was in the lower part of the silo and fed last, the difference may have been partly due to the declining pasture as the summer advanced.

PHOSPHORIC ACID-TREATED ALFALFA SILAGE VS. CORN SILAGE

Lots 7 and 8 were fed successively against corn silage. Two groups of seven cows each were fed through two alternate 50-day periods. The cows were paired as evenly as possible according to weight and milk production. Feeding was conducted according to Morrison's "good production" standard. Hay and grain were kept at a minimum and silage was fed liberally. The grain rations were varied in protein content to balance the difference in protein content between the legume silage and the corn silage. An attempt was made to feed equal amounts of dry matter in the corn and legume silages and to adjust the amount of silage to some extent to the weight of the cows.

While on the acid-silage ration the cows produced 4.56 per cent less milk than when on the corn-silage ration. The seven cows going from acid-alfalfa silage in the first period to corn silage in the second period declined only 583 pounds of milk, while the seven cows going from the corn silage to the acid-treated silage declined 1,278 pounds. The seven cows gained a total of 444 pounds in weight while on the corn-silage ration and lost 65 pounds in weight while on the acid-silage ration. Feed consumption was practically the same during both periods.

EFFECTS ON THE COW

Analyses of the urine from the cows receiving the phosphoric acid-treated silage showed an increase of nitrogen and a small decrease of the pH and bicarbonates. The decrease of pH and bicarbonates probably would have been greater if legume hay and limestone had not been fed. The feeding of the phosphoric acid increased the phosphorus content of the dry matter of the feces 33 per cent but at too high a cost to be significant as a fertilizer.[4]

[4]The study of the feces was made by C. J. Schollenberger of the Department of Agronomy, Ohio Agricultural Experiment Station.

These results indicate that phosphoric acid-treated alfalfa silage is not equal to corn silage in feeding value when the protein in the rations is equalized. The difference in production may have been due to the grain in the corn silage. It would require approximately 2 bushels of corn per ton of hay-crop silage to equalize the total digestible nutrients.[5]

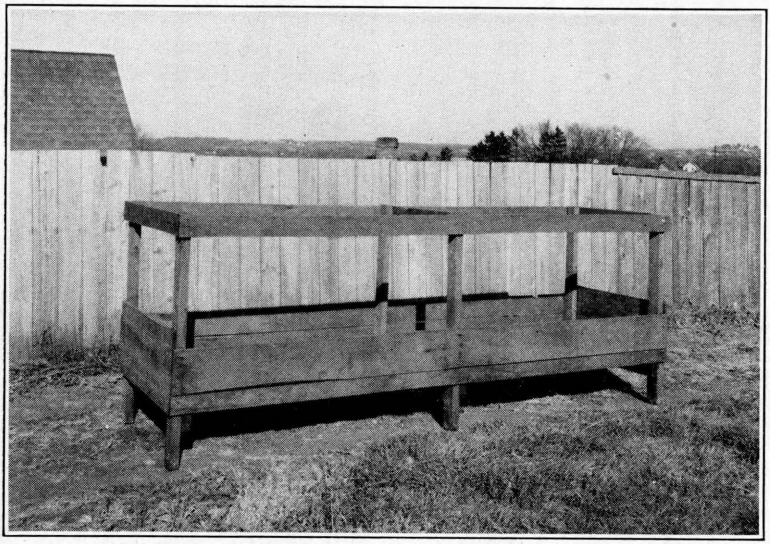


Fig. 4.—Feeding rack used to compare the palatability of silages fed to groups of dairy animals.

MOLASSES-TREATED SILAGE

Prior to the war, molasses had become the most commonly used preserving agent in the making of legume or other hay-crop silage. The general opinion is that molasses aids in preserving the crop and that it adds to the palatability and feeding value of the silage. It is less disagreeable to apply than acids and has high energy value. It is not known how much of its food value is lost from the silage.

The results of treating 15 lots of silage with molasses are here reported. These are compared with seven lots made from the same crops (see table 2) at the same time but made without molasses and with one lot made with phosphoric acid. The air-dry matter, pH, carotene content, and quality of these 15 lots and the silages compared with them are presented in table 2. The lots between the lines in this table were compared directly.

Lot 1.—Two small silos (1½-ton capacity each) were filled with a mixture of alfalfa, clover, and fall grasses. The material in one was treated with 33 pounds of molasses per ton of the mixture. The silos were opened 183 days after they were filled. Both silages were reported good, but the one containing the molasses was slightly better. The untreated lot was a little too dry.

[5]A more detailed report of this work will apear in a later publication.

TABLE 2.—Summary of molasses-treated hay-crop silages*

Lot	Crops used	Molasses per ton	Days in silo	Air-dry matter	pH	Carotene	Quality
		Lb.	*No.*	*Pct.*		*P. P. M.*†	
Check	Alfalfa-clover-grass	None	183	.....	.....	.....	Good; a little dry
1	Alfalfa-clover-grass	33	183	.....	.....	.....	Good+
Check	Alfalfa-clover-weeds	None	25	35.4	4.46	105.6	Good
2	Alfalfa-clover-weeds	40	25+	29.2	4.14	141.5	Good
Check	Alfalfa-clover-weeds	None	60	34.0	4.13	118.2	Excellent
3	Alfalfa-clover-weeds	40	60	34.0	4.04	140.0	Excellent
4	Alfalfa-clover-weeds	60	60	36.0	4.05	106.8	Excellent
5	Alfalfa-clover-weeds	80	60	30.0	4.09	149.9	Excellent
6	Alfalfa-clover-weeds	100	60	34.0	4.06	92.7	Excellent
7	Alfalfa-clover	40	45	22.2	4.61	248.8	Good; juice lost
Check	Alfalfa-clover	None	42	32.4	4.38	96.5	Good
8	Alfalfa (snow-fence silo)	40	.....	23.5	4.40	179.1	Good
Check	Alfalfa (snow-fence silo)	None	.....	31.2	6.13	86.1	Good
9	Pasture—bluegrass, orchard grass, dandelions, and clover	40	45	21.4	3.93	411.1	Good
Check		None	45+	.....	.....	.....	Slightly off flavor, good
10		40	45+	30.5	4.41	349.7	Slightly off flavor, good
Check	Red clover upper half	None	30	23.9	4.44	243.2	Good; juice lost
11	Red clover lower half	40	30+	28.7	4.12	470.0	Good, juice lost
12	Red clover small silo	60	30	24.5	4.07	308.0	Good; juice lost
13	Red clover small silo	80	30	.....	.....	.....	Good; juice lost
Check	Alfalfa upper half	Wilted	.....	34.0	4.81	113.2	Good
14	Alfalfa lower half	40	.....	27.5	4.03	230.0	Good
15	Alfalfa	80	34	38.0	.....	138.6	Good+
Check	Alfalfa	10 phosphoric acid	34	32.2	4.60	208.4	Good
Average	.....	None	.....	31.8	4.44	135.3	Good
Average	.....	Molasses	.....	30.6	4.19	186.5	Good+
Differences	.....	.....	.....	1.14	0.25	52.2	.....

*The silages between lines are compared.
†Parts per million on a dry basis.

Lot 2.—Two silos having 25-ton capacity each were filled with an alfalfa, clover, and weed mixture containing 34.1 per cent dry matter. One was treated with 40 pounds of molasses per ton; the other was untreated. The molasses-treated silage was opened 25 days after it was ensiled, and the other later. These two silages were much alike in quality and were graded good. Both were palatable to cows.

Lots 3, 4, 5, and 6.—Five 50-gallon oil drums were filled from the same crop of alfalfa, clover, and weeds as used in lot 2. The silage in one drum was left untreated. The others were treated with 1, 3, 4, and 5 per cent of molasses, respectively. All of the five silages were graded excellent when the drums were opened 60 days later. The higher rates of molasses had little additional effect on the pH, or acidity, and the highest loss of carotene in this trial was in the lot having the highest amount of molasses.

Lot 7.—Two 25-ton silos were filled with an alfalfa-clover mixture containing 18 per cent air-dry matter in the field. One silo was filled without any wilting of the crop and 40 pounds of molasses per ton were added. There was a rather large loss of juice from this silo. When opened 45 days later the air-dry-matter content of the silage was found to be 22.2 per cent and the carotene content 248.8 parts per million on a dry basis.

The material put into the other silo was rained on after mowing and lay out for 2 days. It was then ensiled without molasses. When opened 42 days later the air-dry matter was found to be 32.4 per cent and carotene 96.5 parts per million. This represents a high loss of carotene.

These two silages were fed free-choice in equal amounts at each feeding to dairy cows. The time the cows were permitted to eat was limited. During this palatability test they ate 3,711 pounds of the untreated silage, as compared to 3,369 pounds of the molasses silage. The palatability may have been affected somewhat by the difference in dry matter. The unwilted silage was below the danger line in dry matter as shown later in the study of dry matter and quality.

Lot 8.—Two snow-fence (temporary) silos were filled with second-crop alfalfa (10). The silage in one was treated with 40 pounds of molasses per ton of material; the other was left untreated. The spoilage on the tops and sides of these silos was heavy, 60 and 48 per cent, respectively, and it was largely in proportion to the time of standing. The silages from the centers were good. They were fed free-choice to cows and compared with corn silage similarly fed. In one comparison, the cows ate 11.94 pounds of untreated and 23.06 pounds of corn silage daily; in the other, they ate 11.27 pounds of molasses silage and 28.96 of corn silage daily. These untreated and molasses silages seemed much alike in palatability, but corn silage was much preferred to either.

Lots 9 and 10.—A 25-ton silo was filled with pasture grasses (unpastured bluegrass in head, orchard grass, dandelions, and clover) treated with 40 pounds of molasses per ton. Two 1½-ton silos were filled with like material. One was treated with 40 pounds of molasses; the other was untreated. These three silos were opened 45 days after filling. All contained good silage, but the material in the two smaller silos was a little off in flavor and the untreated lot was a little too dry. The silage in the larger silo was the only lot of molasses-treated silage in our experience with a pH below 4.0 (3.93). Note that it was not a legume silage. It consisted mostly of grasses.

Ensiling a crop of this kind constitutes a method for utilizing excess pasture and for making it available for feed during the short-pasture period.

Lots 11, 12, and 13.—A 25-ton silo was filled with comparatively clean, medium red clover. Two per cent of molasses (40 pounds per ton) was added to the material going into the lower half. Much juice ran out from the sides of this silo. When this silo was opened 30 days later, the silage was found to be very compact. The upper untreated half seemed as good or a little better than the lower half which was treated with molasses. Much of the molasses may have been lost with the heavy loss of juice. The untreated silage was more palatable to cows.

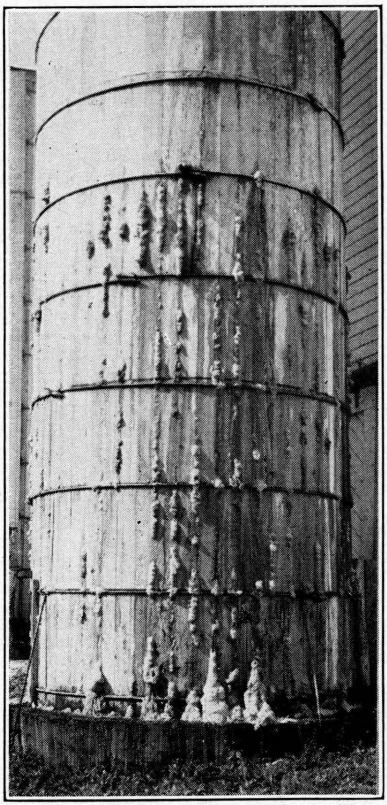


Fig. 5.—Juice leaking from clover silage in a 20-ton silo. Excessive leakage is most likely to occur from crops having less than 25 per cent dry matter.

Two smaller silos were filled from the same crop; to these 60 and 80 pounds of molasses were added per ton. The silages in these silos were about equal in quality to those in the larger silo.

Lot 14.—A 25-ton silo was filled with comparatively clean third-crop alfalfa. Forty pounds of molasses per ton were added to the material going into the lower half; the rest was left untreated. The forage was cut rather coarse and did not pack well, but both silages were graded as good. Dairy cows fed the treated and untreated silages consecutively ate daily 11 pounds more (same dry basis) of the wetter molasses-treated silage. At the same time they ate a little less grain and hay and produced slightly less milk, indicating that the untreated and treated silages were about equal in value for milk production.

Lot 15.—Two small silos were filled with third-crop alfalfa. The silage in one was treated with 80 pounds of molasses and that in the other with 10 pounds of phosphoric acid per ton of green material. These silos were opened 34 days later. The dry matter was 38 per cent in the molasses-treated silage and 32.2 per cent in the acid-treated silage. In a palatability test cows ate more of the acid-treated silage. Both silages were graded good.

Molasses in the amounts used in these 15 lots seemed to have some beneficial effect on quality but did not reduce the pH below 4.0, except in the case of one non-legume crop. It seemed to have some effect in preserving carotene.

A more detailed report on molasses-treated silage will appear in a later publication.

GROUND CORN

Corn meal and corn-and-cob meal are being added to silages made from hay crops supposedly for the purpose of providing fermentable carbohydrates. Early reports indicate favorable results from their use. They consist largely of carbohydrates, but there is some question about their ability to replace sugars in providing readily fermentable material. They add grain and increase the dry-matter content, which is an advantage when low dry-matter material is being ensiled. Corn meals are usually more available, cheaper, and more easily applied than most other materials used as preservatives.

Reed and Fitch (17) at the Kansas Station (1917) used corn meal at the rates of 1 to 10 and 1 to 20 (1 of corn meal to 10 or 20 of the crop). They reported excellent silage with both rates.

Henning (8) found that the addition of 5 per cent of corn meal resulted in no improvement over untreated material, but both silages were unsatisfactory.

Stone et al. (19) found 200 pounds of corn meal per ton about equal to 80 pounds of molasses.

Bohstedt and associates (3) state that it appears that a larger proportion of the starch of the corn grain is converted into preservative acids than was heretofore thought to be the case and that corn has at least fair preservative properties. Two pounds of sulfuric acid per ton of silage aided the process. They considered that 150 pounds of corn were equal to 60 pounds of molasses and that the outstanding effect of adding corn was an increase in palatability of the silage.

In the tests here reported eight lots of hay-crop silage have been treated with ground shelled corn and compared directly with similar lots without a preservative and with one lot treated with phosphoric acid.

Lots 1 and 2.—In June 1939, three small silos of 1½-ton capacity each were filled from a crop of alfalfa, alsike, and red clover. The material contained about 23 per cent of dry matter.

The material put into the first silo was left untreated; that put into the second and third silos was treated with 100 and 200 pounds of ground yellow corn per ton, respectively.

The first and second silos were opened 59 days later. The silages were graded good, and the one containing 100 pounds of ground corn had a little more pleasant odor than the untreated silage. The third silo, containing the 200 pounds of meal, was opened 65 days after it was filled. Water was added to this silage when it was made to hold down the dry-matter content which would have been increased by the additional ground corn. The silage was graded as good; in fact, much the same as that with 100 pounds of corn. The untreated silage was slightly inferior to the other two. For dry matter, pH, and carotene in these and subsequent lots see table 3.

Lots 3 and 4.—Four small silos were filled from a rather pure first crop of alfalfa, containing 19.5 per cent of dry matter. The material placed in the first silo was left untreated; that in the second silo received 100 pounds of ground corn per ton; that in the third silo received 16 pounds of phosphoric acid; and that in the fourth silo, 150 pounds of ground corn. The first and second silos were opened 58 days after they were filled. The quality of the silage in each was poor; the color and odor were better in that with the ground corn. The third, containing the phosphoric acid, was opened after 59 days. The silage was graded poor. The fourth, with 150 pounds of corn, was opened

65 days after it was filled. The silage was graded fair. It was a little better than the other three. All had an undesirable odor. The low quality in these four silages probably was due to the low dry-matter content. There was some benefit from the corn meal.

TABLE 3.—Summary of corn meal-treated legume silages

Lot	Crop used	Corn meal added	Air-dry matter	pH	Carotene	Eaten free-choice	Days in	Quality
		Lb. per ton	*Pct.*		*P.P.M.*	*Lb.*	*No.*	
Check....	Alfalfa-clover.....	None	22.0	4.12	192.0	.....	59	Good
1.....	Alfalfa-clover.....	100	25.2	4.15	188.5	.....	60	Good
2.....	Alfalfa-clover.....	200	25.7	4.10	228.8	.....	65	Good
Check....	Alfalfa	None	19.3	4.45	362.7	.....	58	Poor
3.....	Alfalfa	100	23.0	4.03	272.8	.....	58	Poor
Check....	Alfalfa	16 of P. acid	20.5	4.10	278.0	.....	59	Poor
4.....	Alfalfa	150	23.8	4.02	288.8	.....	65	Fair
5.....	Alfalfa-clover.....	147	24.7	4.55	168.6	.....	57	Poor
Check....	Alfalfa-clover.....	None	24.0	4.43	222.4	.....	57+	Poor
6.....	Alfalfa-clover.....	106	26.0	4.44	267.3	.....	57+	Poor
Check....	Alfalfa-grass	None	23.7	4.90	.....	1,144	177	Good
7.....	Alfalfa-grass.....	115	26.5	5.45	.....	919	177	Good—
Check....	Alfalfa-grass.....	None	27.0	4.90	.....	1,120	203	Fair+
8.....	Alfalfa-grass.....	200	31.0	4.75	.....	1,016	203	Fair+
Average.	.....	Corn meal	25.7	4.43	238.8	.....	.....	.....
Average.	.....	None	23.2	4.56	259.0	.....	.....	.....

Lots 5 and 6.—A 25-ton capacity silo was filled with a mixture of alfalfa, alsike, and red clover. The upper section was treated with 146 pounds of ground shelled corn per ton, the middle section was untreated, and the lower section was treated with 106 pounds of ground corn per ton. New tar roofing paper was placed between the sections to prevent juice from leaking readily from one section to the other.

The top section was opened 57 days after it was filled; the lower sections were opened as the silage was fed out. All of these silages were graded poor. They had a disagreeable pungent odor, that in the untreated section bordering on a foul odor. The undesirable odor was least pronounced in the lower section with 106 pounds of corn meal and a little higher dry matter. The corn meal had a favorable effect on the odor but it had little effect on the pH. The carotene was not affected, as shown in table 3.

Silage in the lower section of the silo often is better than that nearer the top. This is thought to be due to increased pressure and consequently to greater exclusion of air. Results obtained with different treated lots in the same silo, therefore, may be somewhat affected by the location in the silo.

Lots 7 and 8.—Four 1½-ton silos were filled with third-crop alfalfa containing about 40 per cent of timothy and other fall grasses. The material in two silos was left untreated; that in one was treated with 115 pounds of ground corn per ton; and that in the other was treated with 200 pounds of ground corn per ton. One of the untreated lots and that treated with 115 pounds of corn were opened 177 days later. The silage in each was graded good. The treated silage seemed less acid and had a less agreeable odor. Both silages were fed free-choice to four cows. Three cows ate more of the untreated silage and one ate more of the treated.

The other two silos were opened 203 days after they were filled. Both silages were considered fair, but the one containing 200 pounds of ground corn per ton was considered better. It had a more pleasant odor and a slightly lower pH (table 3). Carotene was not determined. When these silages were fed free-choice to cows more of the untreated silage was eaten, but the difference was not large. This did not agree with the human estimate of their quality.

The results obtained from the addition of corn meal in these eight tests have been somewhat disappointing; but in all cases except one, the lots containing the meal have graded slightly better than the untreated lots. The average pH of the treated lots was only 0.13 unit lower than the average of the untreated lots, and the carotene content was not affected. While the results were not outstanding, there was some benefit from the meal. Most of the poor silages were below the desired percentage in dry matter. The lots were not large enough to permit feeding or extended palatability tests.

The addition of corn was made by hand and possibly a good distribution was not obtained. Some subsequent work, not now ready for publication, indicates more favorable results from the addition of corn-and-cob meal. Its addition may be one of the most practical treatments. The dry-matter content of the ensiled mass is increased markedly by the addition of the corn, which is of decided advantage when crops of low dry-matter content are being ensiled. Whether the corn performs any other preservative function is not established.

SOLID CARBON DIOXIDE

(DRY ICE)

It was assumed that hay-crop silage could be well preserved if it could be kept saturated with carbon dioxide, thus excluding the air. Solid carbon dioxide was suggested. Erf (5) reported good results from its use.

Two 1½-ton silos were filled with alfalfa containing 32 per cent of air-dry matter. The forage was ensiled as soon as cut and 50 pounds of cracked Dry Ice per ton were added in one silo. The forage in the other silo was left untreated. As ensiled, the alfalfa contained 190 parts of carotene per million of dry matter. When these silos were opened, the silages were fed free-choice against corn silage to dairy cows. The cows ate 20.6 pounds of corn silage and 6.34 pounds of Dry-Ice silage in one comparison and 28.4 pounds of corn silage and 5.9 pounds of untreated silage in another comparison. These results indicate that the untreated silage and the carbon-dioxide silage were about equal in palatability and that corn silage was much more palatable than either. Both silages were graded good. The aroma was more like that of hay than of silage. This system of preserving silage seems impractical.

MIXTURES

ALFALFA AND WHEAT

Wheat sowed in a thin stand of alfalfa at the rate of one bushel per acre gave a good crop (7.25 tons per acre) and made good silage (14). There were about 2 parts of wheat to 1 of alfalfa by weight. Less wheat and more alfalfa probably would have made a better silage.

The silage was fed against alfalfa hay to cows on pasture in July and August. The large amount of straw seemed to reduce the palatability somewhat. The cows receiving the hay ate a little more dry matter, other than pasture, and produced a little more milk. The difference was small. More milk was produced per unit of dry matter from the alfalfa-wheat-silage ration.

In another trial in which wheat and clover were grown separately and ensiled together good results were obtained.

ALFALFA AND CARROTS

A small silo was filled with alfalfa and Danver's carrots. This silo was opened about 60 days later (16). It contained very good silage which was highly palatable to the cows. The pieces of carrot were softened somewhat. Carrots are low in dry matter; therefore, legumes should have 30 or more per cent of dry matter if ensiled with carrots. As ensiled, the mixture in this silo contained 30.7 per cent dry matter and 257 parts per million of carotene (on the dry basis). The silage as taken out contained 27.2 per cent dry matter and 255.9 parts per million (dry basis) of carotene. The pH before ensiling was 5.78, and when taken out it was 4.36.

Carrots ensiled with rather ripe corn made very good and highly palatable silage (16).

UNTREATED SILAGES

King (9), Eckles and Palmer (4), Reed and Fitch (17), and Woodward and Shepherd (22) have shown that good legume silage can be made without a preserving agent if the dry-matter content is properly adjusted.

TABLE 4.—Summary of untreated hay-crop silages

Kind of crop	Days in silo	Air-dry matter	pH	Carotene	Quality	Comments
	No.	*Per cent*		*P.P.M.*		
Alfalfa and weeds	68	34.0	4.13	118.2	Excellent	
Alfalfa-clovers	59	22.0	4.12	191.4	Excellent	
Sweetclover		36.7			Good	
Alfalfa-clover-grass	183	34.0			Good	
Alfalfa-weeds	25	35.4	4.46	105.6	Good	Some mold at bottom
Corn-soybeans-weeds		31.8	4.04	61.2	Good	
Alfalfa	75	31.2	6.13	68.1	Good	
Alfalfa	38	28.1	4.51	81.1	Good	
Pasture grasses	75	30.5	4.41	386.9	Good	
Red clover	35	23.9	4.44	243.7	Good	Leaked freely
Alfalfa	39	34.0	4.81	113.1	Good	
Alfalfa-clovers	78	21.3	4.08	284.4	Good	
Alfalfa-timothy	180	23.5	4.90		Good	
Alfalfa-clover-grass	271	27.7	4.92		Good	
Alfalfa-clover-wheat	55	30.9		130.0	Fair	Got wet in field
Alfalfa	44	32.4	4.38	96.5	Fair	Got wet in field
Alfalfa-timothy	180	33.2	4.90	261.4	Fair	
Alfalfa-clover-grass		24.4	5.15	298.7	Fair	
Alfalfa		29.7	4.39	199.7	Fair	Top too dry
Alfalfa-weeds		20.5	5.54	338.0	Fair	Wet, bad odor
Alfalfa-clovers		19.0	5.44	120.1	Poor	Too wet
Alfalfa	57	24.0	4.43	222.4	Poor	Bad odor
Alfalfa		19.3	4.05	362.7	Poor	Bad odor

The results from 23 lots of untreated hay-crop silage are reported here. They consisted of alfalfa, red clover, sweetclover, mixtures of alfalfa, clovers, and grasses, and mixtures of soybeans and corn. The length of time these crops remained in the silos varied from a few days to 271 days before the silos were opened and feeding began.

The dry-matter content ranged from 19.0 to 36.7 per cent, while the pH ranged from 4.04 to 6.13. These untreated silages were rated as follows: 2 excellent, 12 good, 6 fair, and 3 poor. All three rated poor contained 24 per cent or less of dry matter. One of the poor lots was compared with another lot made of the same crop but treated with 16 pounds of phosphoric acid. The acid-treated silage also was poor.

It seems that the chances of getting acceptable untreated silage are good so long as the dry matter is between 25 and 40 per cent. The results of these 23 lots are summarized in table 4.

DRY MATTER AND QUALITY

The dry-matter content of hay crops when ensiled is probably the most important factor in securing good silage (4, 8, 15, 17, 22).

Stone et al. (19) of the Pennsylvania Station presented data on 39 lots of silage which, when arranged in order of their dry-matter content, show the following: of 19 lots containing from 27 to 39 per cent dry matter, 8 graded excellent, 9 good, and 2 fair; while of 18 lots containing from 20 to 27 per cent dry matter, 2 graded excellent, 2 good, 4 fair, and 10 poor.

The results of 69 lots of silage are arranged in the order of their dry-matter content in table 5. Treated and untreated silages are included. The silages graded excellent are all among the lots containing 30 to 36 per cent of dry matter. All poor lots except one contain less than 25 per cent dry matter. Of the 21 lots with less than 25 per cent of air-dry matter, 10 were graded below fair on a scale of excellent, good, fair, and poor.

The higher dry-matter contents were obtained in most cases by wilting. In a few cases they were caused by more mature forage.

These results indicate quite clearly that the dry-matter content is an important, if not the most important, factor in making good hay-crop silage and that 25 per cent of air-dry matter is about the lowest limit of safety. These results agree with King (9), Eckles and Palmer (4), Woodward and Shepherd (22), and Stone et al. (19).

Unfortunately, there is no general rule that will serve as a guide as to the dry-matter content of standing crops or to the rate of drying after cutting. Experience probably will be the best teacher. A few generalizations can be made, however, that might be helpful.

First cuttings of clovers and alfalfa in the pre-bloom or early-bloom stage are remarkably low in dry matter, particularly if the weather is wet and the growth heavy. Dry-matter content below 18 per cent is the rule under such conditions. Silage made from crops so low in dry matter is quite likely to be of poor quality, and heavy leakage is to be expected. Several hours of wilting or heavy applications of dry material, such as corn-and-cob meal, are needed to bring the dry matter to a desirable level. Delaying cutting also will result in a higher dry-matter content because plants increase rather rapidly in dry matter as they approach maturity. Later cuttings of hay crops will usually have 25 per cent or more of dry matter. Grass crops tend to have somewhat more dry matter than the legumes at corresponding stages of growth.

Simple equipment for the rapid determination of dry matter in crops is available which would be useful for other purposes as well as for guiding the silage- and hay-making operations. This might be owned to advantage by groups of small farmers or individually by the large operator.

The carotene content is generally higher in the low dry-matter silages. This may be due to the loss of carotene in drying before ensiling. The pH values do not seem to be related to the dry-matter content.

TABLE 5.—The quality of hay-crop silages, arranged in order of dry-matter content

Crops used	Treatments	Air-dry matter	pH	Carotene	Quality
	Pounds per ton	*Pct.*		*P.P.M.*	
Alfalfa	40 molasses	38.0		138.5	Good
Sweet clover	None	36.7			Good
Alfalfa, some weeds	60 molasses	36.0	4.05	106.8	Excellent
Alfalfa, some weeds	None	35.4	4.46	105.6	Good
Oats and stover	None	34.1	4.75		Good
Alfalfa-clover grass	None	34.0			Good
Alfalfa-clover grass	Molasses	34.0			Good
Alfalfa-weeds	None	34.0	4.13	118.2	Excellent
Alfalfa-weeds	20 molasses	34.0	4.04	140.0	Excellent
Alfalfa-weeds	60 molasses	34.0	4.06	92.7	Excellent
Alfalfa	None	34.0	4.81	113.1	Good
Alfalfa	None	34.0	5.49	79.0	Good
Alfalfa-grass	None	33.2	4.90		Fair to good
Alfalfa	A.I.V. method	32.7	4.07	71.2	Good
Alfalfa	20 P. acid	32.5	4.66	66.0	Good
Alfalfa	None	32.4	4.38	95.5	Fair to good
Alfalfa	10 P. acid	32.2	4.65	208.4	Good
Corn-soybeans	None	31.8	4.04	61.2	Good
Corn-carrots	None	31.7	3.70	104.5	Good
Alfalfa-corn	None	31.3	3.94	79.1	Good
Alfalfa	None	31.2	6.13	86.1	Good
Alfalfa-clover-wheat	None	30.9		130.0	Fair to good
Alfalfa	10 P. acid	30.5	4.81	139.3	Good
Pasture grasses	None	30.5	4.41	386.9	Good
Alfalfa	Dry Ice	30.2	4.32	96.7	Good
Alfalfa	A.I.V. method	30.2	3.69	221.6	Excellent
Alfalfa and weeds	80 molasses	30.1	4.09	149.9	Good
Alfalfa	30 P. acid	30.0	4.26	176.4	Good
Alfalfa	None	29.7	4.39	199.7	Fair to good
Alfalfa and weeds	40 molasses	29.6	4.14	141.5	Good
Red clover	40 molasses	28.7	4.12	470.0	Good
Alfalfa-clover-grass	Wilted	28.7	4.92		Good
Alfalfa-clover	16 P. acid	28.5	4.15	249.3	Good
Alfalfa	None	28.1	4.51	81.1	Good
Alfalfa-clover-grass	None	27.7	4.92		Fair to good
Alfalfa-clover	A.I.V. method	27.7	4.35	50.0	Good
Alfalfa	40 molasses	27.5	4.03	230.0	Good
Alfalfa	29 P. acid	27.5	5.06	129.1	Good
Alfalfa-clover	A.I.V. method	27.2	4.34	42.1	Fair +
Alfalfa-carrots	None	27.2	4.36	255.9	Good
Alfalfa	16 P. acid	27.1	4.48	293.8	Good
Alfalfa-timothy	115 corn meal	26.5	5.45		Good
Alfalfa	None	26.3	4.32	77.5	Good
Alfalfa-clover	106 corn meal	26.0	4.44	267.3	Poor
Alfalfa	Dry Ice	25.9	4.52	96.4	Good
Alfalfa-clover	200 corn meal	25.7	4.10	228.6	Good
Alfalfa-wheat	None	25.4	4.12	103.4	Good
Alfalfa-clover	100 corn meal	25.2	4.15	188.5	Good
Alfalfa-clover	147 corn meal	24.7	4.55	168.6	Fair to good
Red clover	80 molasses	24.5	4.07	336.0	Good
Alfalfa-clover-grass	80 molasses	24.4	5.15	298.7	Fair
Alfalfa-clover	None	24.0	4.43	222.4	Poor
Red clover	None	23.9	4.44	243.7	Good
Alfalfa	150 corn meal	23.8	4.02	288.0	Poor
Alfalfa-timothy	None	23.5	4.90		Good
Alfalfa	20 molasses	23.5	4.46	179.2	Good
Alfalfa-weeds	A.I.V. method	23.0	3.78	367.6	Fair—
Alfalfa	108 corn meal	23.0	4.03	272.8	Poor
Alfalfa	40 molasses	22.2	4.61	248.8	Good
Alfalfa-clover	None	22.0	4.12	191.4	Good+
Pasture grasses	40 molasses	21.4	3.93	411.1	Good
Alfalfa-clover	None	21.3	4.08	284.4	Good
Alfalfa-clover-grass	Corn meal	21.0	4.45		Poor
Alfalfa-weeds	None	20.5	5.54	338.0	Fair—
Alfalfa	16 P. acid	20.5	4.10	278.0	Poor
Alfalfa	A.I.V. method	19.8	5.02	245.6	Good
Alfalfa	None	19.3	4.05	362.7	Poor
Alfalfa-clovers	None	19.0	5.44	120.1	Poor
Alfalfa	None	17.8	5.25	339.8	Poor

Low pH and high carotene values are desirable in silage. A low pH indicates that fermentation has progressed to a point where undesirable reactions, such as protein cleavage, do not occur. Carotene values are rough indices of nutritive value. Carotene (provitamin A) is necessary for proper nutrition of dairy cattle, and a higher intake of carotene than the minimum required for satisfying body needs is reflected in increased yellow color and a higher vitamin A content of the milk produced. On the other hand, a high-carotene silage probably is low in vitamin D. This suggests the need for feeding sun-cured hay along with silage in the winter time.

As used throughout this report the term "quality" is based on a human estimate of the acceptability of the silage to cows. Odor, flavor, color, and actual spoilage were used to evaluate quality. Carotene and pH values were obtained as part of the routine chemical analyses and are included in table 5 to show the correlation or lack of correlation between these factors and overall "quality."

SUMMARY AND CONCLUSIONS

A. I. V. SILAGE

Two experiments were conducted with legume silage treated by the A. I. V. method. Good silages were obtained.

The feeding of A. I. V. silage caused a marked decrease in the pH and bicarbonates and a marked increase in the ammonia nitrogen in the urine of cows. These marked changes did not occur when silages containing the naturally developed, or organic, acids were fed.

The carbon-dioxide capacity of the blood was decreased very slightly; the calcium and phosphorus remained normal.

Feeding the A. I. V. silage as the only roughage through the winter season seemed to cause no marked effects on the cows. Limestone was fed with the acid silage. When fed against good hay from the same kind of crop, cows consumed about 13 per cent more dry matter in the silage ration and produced more milk, but they produced less milk per unit of dry matter consumed.

The sulfuric and hydrochloric acids were expensive, difficult to handle, and injured machinery. This method is not recommended.

PHOSPHORIC-ACID SILAGE

Nine lots of hay-crop silage were treated with phosphoric acid in amounts per ton ranging from 10 to 30 pounds. In no case did this treatment reduce the pH of the silage below 4.0. The average was pH 4.5. The average pH of compared untreated lots was 4.53.

All lots of silage treated with phosphoric acid, as well as the untreated lots compared with them, were about equally good.

Phosphoric acid gave no higher preservation of carotene than did the untreated silages directly compared.

Cows fed phosphoric-acid silage in comparison with corn silage gained in weight while on the corn-silage ration and lost in weight while on the phosphoric-acid ration.

The ammonia in the urine of cows fed phosphoric-acid silage was increased and the pH and bicarbonates were decreased. Probably, it is not wise to feed phosphoric-acid-treated silage too liberally.

MOLASSES SILAGE

Fifteen lots of hay-crop silage were treated with molasses in amounts ranging from 33 to 100 pounds per ton of green crop. These lots seemed only slightly better than seven untreated lots with which they were compared.

In only one lot of molasses silage (non-legume) was the pH reduced below 4.0. The average pH of the molasses silages was 4.19 and of the untreated lots 4.44.

The carotene was generally better preserved in the molasses silage, but the palatability did not seem to be markedly increased.

GROUND CORN

Eight lots of legume silage were treated with ground shelled corn in amounts of 100 to 200 pounds per ton of green material. The corn-treated lots seemed slightly better than the untreated.

Later experiments not included in this publication indicate that ground ear corn, or corn-and-cob meal, may replace the ground shelled corn with like results.

DRY ICE

Legume silage treated with Dry Ice was much the same as the untreated silages made from the same kind of material.

MIXTURES

Alfalfa and carrots and alfalfa and green wheat made good silage.

UNTREATED SILAGE

Twenty-three lots of untreated silage indicate that this method is fairly reliable if the dry-matter content is kept between 25 and 40 per cent.

EFFECT OF DRY-MATTER LEVEL

Studies on 69 lots of hay-crop silage indicate clearly that the dry-matter content of the material ensiled is an important, if not the most important, factor in determining the quality of the resulting silage regardless of the preservation treatment used.

LITERATURE CITED

1. Bechdel, S. I., R. W. Stone, P. S. Williams, and F. R. Murdock. 1941. Legume silage in dairy feeding. Pa. Agr. Exp. Sta. Bull. 411.

2. Bender, C. B., and D. K. Bosshardt. 1939. Grass silage, a critical review of the literature. Jour. Dairy Sci. 22: 8: 637-651.

3. Bohstedt, G., W. H. Peterson, and G. B. Bahler. 1941. Corn meal as a silage preservative. Jour. Dairy Sci. 24: 6: 513-514.

4. Eckles, C. H., and L. S. Palmer. 1916. Silage feeding (corn and clover). Mo. Agr. Exp. Sta. Bull. 22.

5. Erf, O. 1936. A new method of preserving green feeds. Jersey Bull. 55: 121.

6. Hathaway, I. L., H. P. Davis, and J. C. Bauer. 1938. The vitamin A content of soybean silage and A. I. V., molasses and corn silage and the effects of feeding these materials on the vitamin A content of milk. Neb. Exp. Sta. Bull. 101.

7. Hayden, C. C., A. E. Perkins, W. E. Krauss, C. F. Monroe, and R. G. Washburn. 1937. Legume silage for dairy cows. Ohio Agr. Exp. Sta. Bimo. Bull. 184: 21.

8. Henning, P. D. 1939. The latest method of silage-making. Farming in South Africa. 11: 199-201.

9. King, F. H. 1897. The construction of silos and the making and handling of silage. Wis. Agr. Exp. Sta. Bull. 59.

10. Krauss, W. E., C. C. Hayden, A. E. Perkins, and R. G. Washburn. 1938. A trial with temporary silos. Ohio Agr. Exp. Sta. Bimo. Bull. 192: 71.

11. Lepard, O. L., E. Page, L. A. Maynard, R. A. Rasmussen, and E. S. Savage. 1940. The effect of phosphoric acid silage on the acid base balance of dairy cows. Jour. Dairy Sci., 23: 10: 1013-1022.

12. Monroe, C. F., C. C. Hayden, A. E. Perkins, W. E. Krauss, C. E. Knoop, and R. G. Washburn. 1938. Feeding value of hay-crop silage. Ohio Agr. Exp. Sta., Bimo. Bull. 194: 155.

13. Peterson, W. H., G. Bohstedt, H. R. Bird, and W. M. Beeson. 1935. Preparation and nutritive value of A. I. V. silage for dairy cows. Jour. Dairy Sci., 18: 1, 63-78.

14. Ohio Agr. Exp. Sta. 58th Ann. Rept. 1939. Wheat and alfalfa for silage. Bull. 617: 46.

15. Perkins, A. E. 1941. Dry matter content of crops in relation to hay and silage making. Ohio Agr. Exp. Sta. Bimo. Bull. 208: 6.

16. ————, C. C. Hayden, W. E. Krauss, R. G. Washburn, and C. F. Monroe. 1944. The preservation and feeding of carrots as combination silages. Ohio Agr. Exp. Sta. Bimo. Bull. 226: 10.

17. Reed, O. E., and J. B. Fitch. 1917. Alfalfa silage. Kan. Exp. Sta. Bull. 217.

18. Smyers, F. 1934. Ensiling of green fodder in Belgium—the influence of the silage on the quality of the milk and derived products. Proc. World's Dairy Cong. Rome, Milan. 1934.

19. Stone, R. W., S. I. Bechdel, H. D. McAuliffe, F. R. Murdock, and C. R. Mahan. 1943. The fermentation of alfalfa silage. Pa. Agr. Exp. Sta. Bull. 444.

20. Virtanen, A. I. 1938. Cattle fodder and human nutrition. Cambridge University Press, England, MacMillan Co.

21. Watson, J. S. 1939. Science and practice of conservation; Grass and forage crops. London, MacMillan Co.

22. Woodward, T. E., and J. B. Shepherd. 1938. Methods of making silage from grasses and legumes. U. S. D. A. Tech. Bull. 611.

This page intentionally blank.